UNIVERSITY OF MICHIGAN

EECS 370

Lab 3:
ARM Assembly

Upcoming Assignments

- Lab 3 due Wednesday 9/20
- Project 1s & 1m due Thursday 9/21
- Homework 1 Monday 9/25

LC2K Instructions Compared to ARM

cheat sheet!

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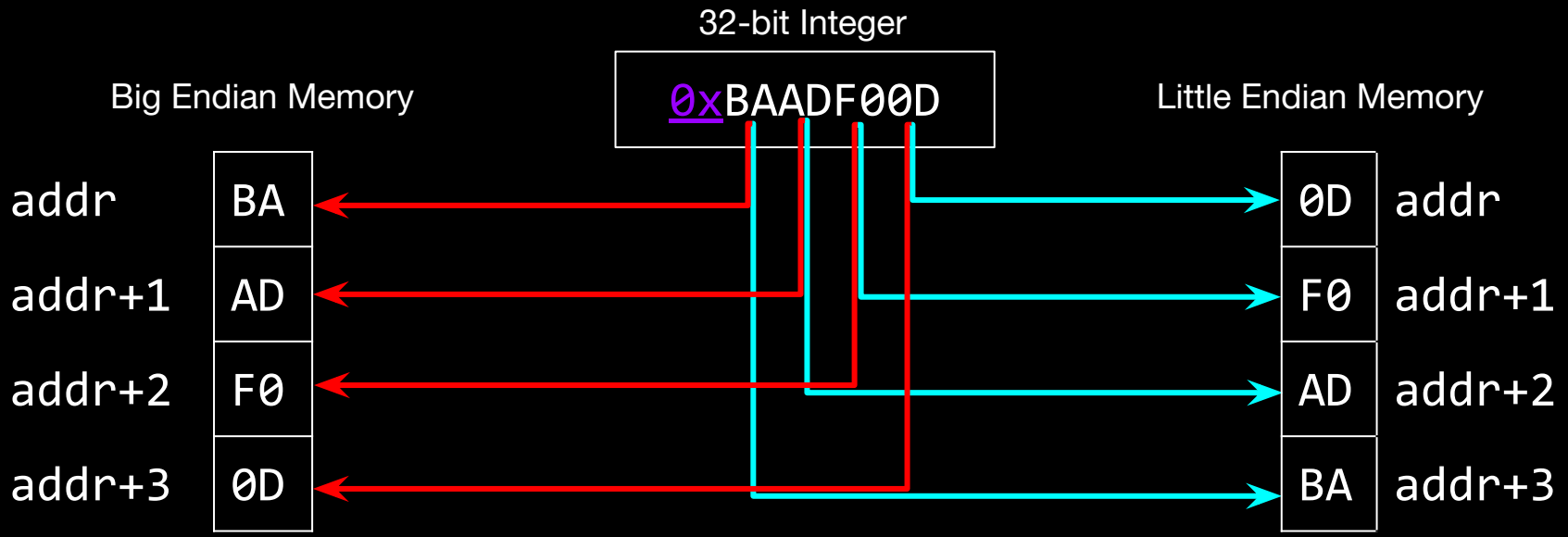
LC2K	ARM	Differences
add (R-type)	ADD	Also ADDI for constants, and SUB/SUBI for subtraction. (LC2K Subtraction: nor the 2nd with itself, add 1, add result to 1st one). MOVZ #0 zeros out reg. We use LSL, LSR for shifts. (Pseudo-instructions: MUL)
nor (R-type)	Load #-1 then EOR/SUB	Much easier to use ORR/ORRI, ADD/ADDI, EOR/EORI. (Note: a NOT instruction exists in pseudocode for ARM overall, but not LEGv8)
lw (I-type)	LDURSW	This is for 32 bits. Also LDUR, LDURH, LDURB.
sw (I-type)	STURW	This is for 32 bits. Also STUR, STURH, STURB.
beq (I-type)	CMP then B.EQ	CBZ branch if zero (beq 0 regB offset), B for unconditional (beq 0 0 offset)
jalr (J-type)	BR (branch reg)	Using BL with #0 right before BR stores return address
halt (O-type)	End of file	
noop (O-type)	NOP	Technically not in LEGv8, but present in ARM overall

Data is Stored in Memory in Chunks

Each chunk is (typically) the size of a single byte

Think of each chunk like a wooden letter block:
To interpret the word, we can rearrange the blocks, but can't change the letters.

Endianness in Byte-Addressable Systems



Big Endian builds the word so the **lowest** address is the MSB.

This can be more natural for humans to think about.

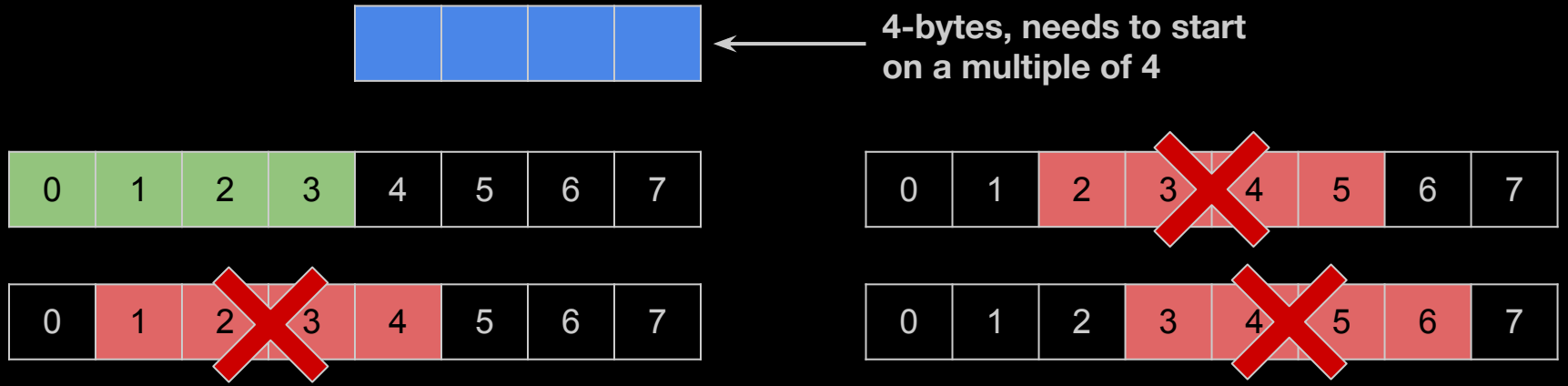
Little Endian builds the word so the **highest** address is the MSB.

Faster for a computer to read, as int ops can start after reading the first byte.

Memory Alignment

In memory, data is aligned to the size of its type

This makes it more efficient to access within memory
and is important for caching (we'll see why later in the course)



The Typical Size of Data Types

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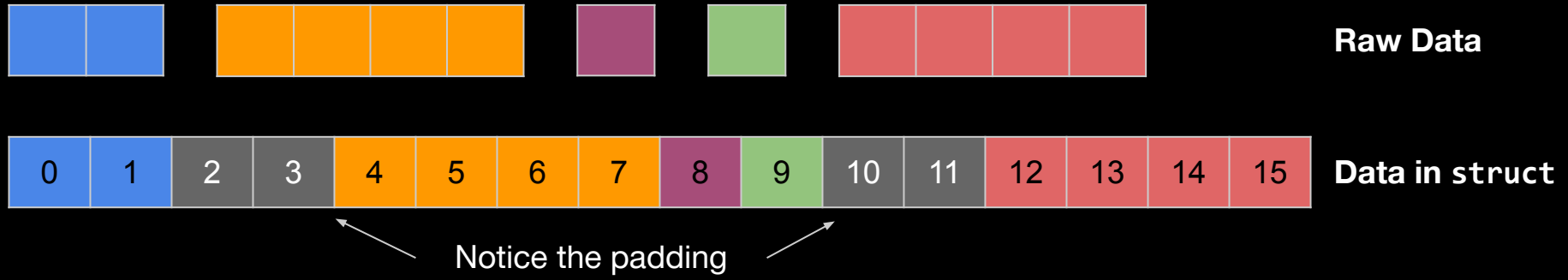
Data Type		Size / Alignment
`char`		1 Byte
`short`		2 Bytes
`int, float`		4 Bytes
`double`		8 Bytes
`long`	*(32-bit Architecture)*	4 Bytes
`long`	*(64-bit Architecture)*	8 Bytes
pointer	*(32-bit Architecture)*	4 Bytes
pointer	*(64-bit Architecture)*	8 Bytes

Aligning Data within a `struct`

Since a `struct` can contain multiple different data types,
we must align the **`struct`** using the ***largest primitive type*** within it

Furthermore, we may need to pad the **`struct`** to keep everything aligned,
even padding the end in case we have an array of **`structs`**



Example: Addressing Data in Memory

Determine the start and end addresses for the following variables.
(Assume a 64-bit system and that the data starts on address 200_{10})

```
struct {
  2 short a;
  4 int b;
  1 char c;
  8 int* d;
    struct {
        int e;
        char f[10];
    } g;
} example;
```

a:	200 - 201	
b:	204 - 207	
c:	208 - 208	
d:	216 - 223	
e:	224 - 227	
f:	228 - 237	
g:	224 - 239	
total:	200 - 239	→ 40 bytes

char c 1 200 - 200
short a. 2 201 - 202
int b 4 204 - 207
struct{
int e 4 208 - 211
char f[10] 212 - 221
g: 208 - 221
224 - 231

Grid View

```
struct {
    short a;
    int b;
    char c;
    int* d;
    struct {
        int e;
        char f [10];
    } g;
} example;
```

offset	+0	+1	+2	+3	+4	+5	+6	+7
base	a	a			b	b	b	b
+8	c							
+16	d	d	d	d	d	d	d	d
+24	e	e	e	e	f	f	f	f
+32	f	f	f	f	f	f	g	g

Struct Memory Optimization (281 Tip)

- We can rearrange the variables in a struct to use as little padding as possible for BOTH 32-bit and 64-bit systems.
- Greedy yet optimal algorithm: start with the largest size primitives, then go down.
  - This also works by starting with the smallest, and working up.
  - And there might be more solutions for a given struct.
- *Count structs as multiples of their largest member, as with alignment.*

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